GLOBAL WATER SECURITY: AN INTRODUCTION

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In April 2010 the Royal Academy of Engineering published a report entitled Global Water Security – An Engineering Perspective. This report was produced by the Institution of Civil Engineers, the Royal Academy of Engineering and the Chartered Institution of Water and Environmental Management, through a Steering Group of 12 specialists working in the field. The Steering Group took evidence (in hearing and written) from a wide range of UK and international experts covering all aspects of water security.

The main drivers for the report were concerns from numerous sources from within government, the professions and learned societies etc, about the increasing challenges arising relating to water security (ie security of supply) and the implications for Britain, both within the UK and internationally. Some of these challenges, threats and opportunities are introduced below.

There are 1.2 billion people living on this earth today with no access to safe drinking water and 2 million people die annually of diarrhoea – still one of the biggest causes of infant mortality on earth today and I tell my first year students that it is engineers that hold the key to reducing significantly this sad statistic, rather than the medical profession. Engineering offers rewarding career opportunities second to none to those young people aspiring to want to save lives or improve the quality of life of our fellow citizens living on this earth today.

There are 2.4 billion people who do not have basic water sanitation and 1 million die annually of hepatitis A. Women in developing countries have to walk typically 3.7 miles to carry water for the family; again engineers could make a huge contribution to the quality of life for these women. Floods often cause significant loss of life and destroy homes, with this year's Pakistan floods leading to 21 million people being homeless. However, the disease associated with the after effects of such floods can often bring far more loss of life to communities and countries than the floods themselves. It is estimated that at any one time more than half the hospital beds worldwide are occupied by people with water related diseases (BMJ, 2004).

So the challenges of water security are immense and Britain does, and can continue to do, so much to help the rest of the world in addressing some of the massive challenges of water security.

Along with these challenges there are two further issues that are exacerbating the current threats to water security. Firstly, there is climate change, where average global temperatures are expected to rise by at least 2°C by the end of this century. If the temperature increases between 2 and 5°C there will be major water resources problems globally, also resulting in significant sea water level rise and causing catastrophic coastal flooding in many parts of the world, such as Bangladesh. Secondly, we are encountering 'the Perfect Storm' in the form of global population growth expected to rise by 2030 from 6 to 8 billion. Associated with this population growth we can expect the demand for food, energy and water to increase by 50%, 50% and 30% respectively. The water, food and energy nexus is crucial to our existence, with water being at the heart of everything; it is

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crucial for our energy supply, food, health, industry, trade etc. If we look at the water stress globally (defined as millions of litres of water available per person per year) from 1960 to 2010, we find that even in the southeast of England water supply is currently particularly stressed. If we predict forward to the 2050s and beyond we see that even the whole of the UK will be facing problems towards the end of this century.

Problems in water supply will relate not only to the 50% increase in human population over the next 30 years; urbanisation is occurring all over the world, which will tend to exacerbate this effect. In countries such as China, for example, people are moving into the major cities while in the UK people are moving more and more to the southeast of England, which is not sustainable.

Food production is also rising, along with industrial production, and new energy sources will be required to support this industrial production and feed the population growth. As countries become richer they will change their diets, as typified for example by the big increase in meat consumption in China. If we now look at the consequences of changing diets and food consumption etc in the context of embedded or virtual water, the global implications are considerable. To produce 1kg of wheat requires 1,300 litres of water, whereas in contrast to produce 1 kg of beef requires 15,000 litres of water, ie over 10 times as much water.

Looking at other commodities, it takes 140 litres of embedded water, nearly a bath full (150 litres), to produce one cup of coffee, and that water is used in another country – such as Brazil – when the coffee is drunk in Britain. One pair of cotton jeans requires 73 baths full of embedded water, which are attributable mainly to the cotton production, and that water is likely to be used in countries such as Egypt, where there are already serious water shortages. The embedded water footprint of the 25 European Union countries bears most heavily on countries such as India and Pakistan, which are the primary sources of cotton supply to the EU. The drying up of the Aral Sea is one example which can be partly attributed to cotton production, though this is not the only cause of the drying up of this water body. The point to appreciate, however, is that the demand for embedded water products in one country can have very serious impacts elsewhere in the world, such as Egypt, for example.

Desalination is one possible solution in large coastal cities, but this process is still relatively expensive and imposes a large carbon footprint, through large energy demands. Research studies being undertaken within our Hydro-environmental Research Centre at Cardiff University have found that salinity levels along the Arabian coast of the Persian Gulf are increasing slowly, potentially due to the rapid growth in desalination plants and this must have long term impacts for the hydro-ecology of this highly stressed water body.

Conservation and water re-use is often a short term solution to a longer term problem. Storage involves water transfer and better integrated water management, with a much more holistic approach to river basin management being required than used hitherto. To increase global water security, improved water quality in river basins and coastal waters is required, along with a reduction in global water pollution. It also goes without saying that global population growth needs controlling. Integrated water management requires a Cloud to Coast (C2C) approach that treats the water cycle as an integrated system, bringing together the professionals who currently specialise in modelling various components of the system, including: hydraulic engineers, hydrologists, biologists etc and with the distribution from the cloud to the coast, through the catchment, groundwater, sewers, rivers, estuaries, needing to be treated as one. Our research centre at Cardiff is currently developing such an integrated approach with consultants Halcrow.

In addressing some of these challenges global actions are needed; in particular, we need the water footprint and the concept of embedded or virtual water to be better understood and more widely promoted. Better technologies and further research is needed for more efficient agriculture. New sustainable sources of water are needed from desalination, recycling and water harvesting. Inter-governmental bodies, such as the WTO, must elevate issues of water security further up their agenda. The public must become more engaged in the challenges we all face with regard to water security; this is a global problem which affects every nation.

There are also key water security Challenges and Opportunities for the UK. For example, population growth is not just a challenge for developing countries; it is also

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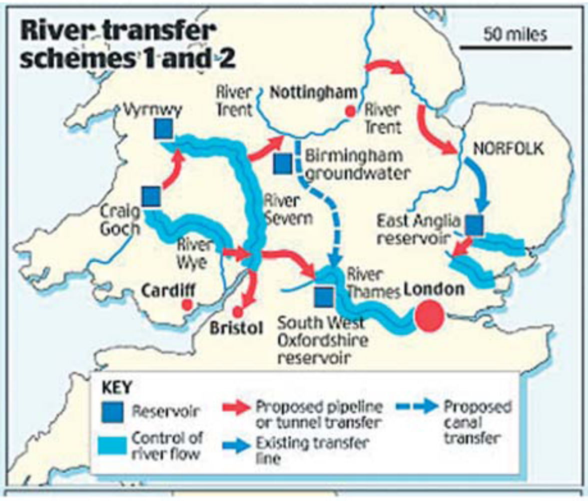


RIVER TRANSFERS

Scheme 1

River transfer from reservoirs in Wales (Vyrnwy and Craig Goch), via Wye and Severn, to the Thames. This includes construction of major pipeline/aqueduct linking Severn to Thames at Lechlade, in Wilts.

Yield: **550 megalitres (121m gallons) a day**

Construction cost: **£328m**

Annual operating costs: **£80.4m**

Cost per megalitre: **£2.48**

Scheme 2

River transfer from Vyrnwy reservoir in Wales, via Severn and Trent, to East Anglia and Essex. This includes construction of pipeline linking Severn and Trent, plus north to south pipelines through Norfolk.

Yield: **200 megalitres (44m gallons) a day**

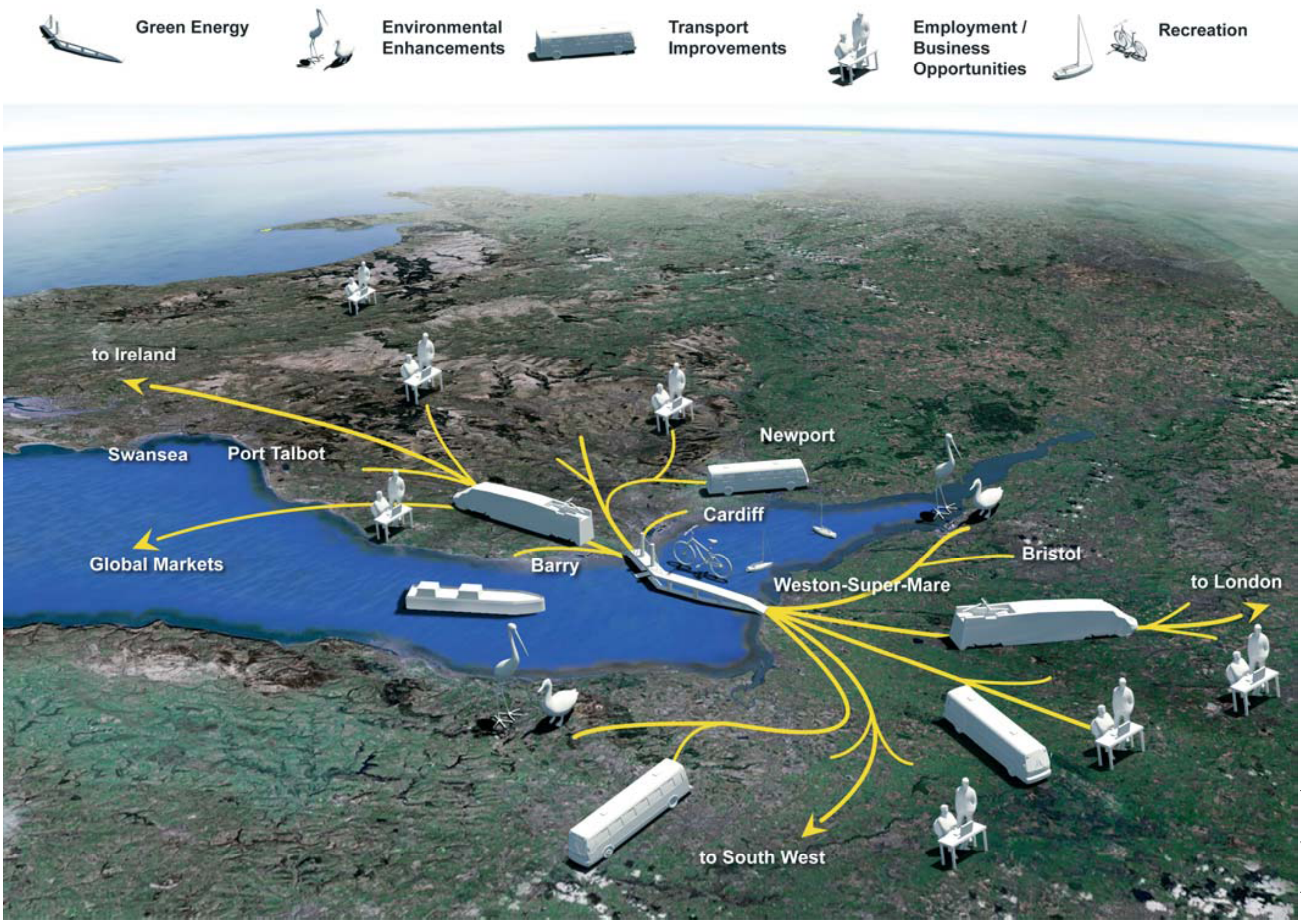
Construction cost: **£188m**

Annual operating costs: **£60.1m**

Cost per megalitre: **£4.30**

an issue that concerns the UK. The population is predicted to grow by nearly 16% over the next 22 years, from 61.8m in 2009 to 71.6m by 2033. This implies a yearly average growth rate of 718,000 per annum and will probably continue to increase at a comparable rate thereafter unless action is taken.

Water stress in the UK is not distributed evenly, with the southeast of England, including London, subjected to serious levels of water stress, while low water stress is located in both the north and southwest of England, but not including Cornwall, which has moderate water stress levels comparable with East Anglia and the East and West Midlands. River transfers offer a solution to water shortages in the South East of England by raising dams in Wales and transferring water via networks of rivers and canals as shown in the illustration provided. Alternatively, the proposed Severn Barrage must be considered as more than a renewable energy project; this project offers the opportunity to create a large water body 1.5 times the size of Lake Garda, with much reduced tidal currents than now, reduced turbidity, and much clearer water; thus creating a huge resource for recreational opportunities etc. This large water body would then provide a great catalyst to encourage more of the UK's population and industry and commerce to re-locate from the South East to the South West of England, making Bristol a larger city, and encouraging some of the population to move from a high (SE) to a low (SW) water stressed region of the UK. One thing is for certain; the current level of population migration to the South East of England is not sustainable – at least in terms of water security!



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GLOBAL WATER SECURITY
Is it achievable? What are the consequences of failure?

Michael Norton MBE CEng
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In his Reith Lectures this year Professor Sir Martin Rees, Astronomer Royal, said "This is a crucial century. The Earth has existed for 45 million centuries. But this is the first when one species, ours, can determine for good or ill – the future of the entire biosphere."

Though Earth is 4/5ths covered with a thin layer of salty water, human life depends on freshwater, as does Earth's incredible biodiversity, a crucial component of human well-being. That freshwater comes courtesy of Earth's greatest engine, the water cycle, but now, in Earth's 45th million century, a global crisis of freshwater scarcity is on our doorstep; a crisis that is accelerating through our unbridled development, burgeoning demand for food and energy, and the effects of climate change.

Only 0.01% of the total global water volume of 1.4 billion cubic kilometres is freshwater, and only 105 thousand cubic kilometres is easily accessible.

This limited volume, which is not uniformly distributed in time or space provides a wide range of functions:

- to sustain human life (consumption and sanitation)
- with nutrients and sunlight for food production
- to support energy production
- to sustain industry
- to maintain our ecosystems, biodiversity environment and landscape

Increasing attention is now being paid to the **Water-food-energy nexus**, a nexus overlain by competition for finance, the impact of international trade flows and climate change impacts.

. . . Population growth means that the earth will have to sustain 2 billion more people in the next 20 years. . .

Even though 13% of water abstractions in Europe are for drinking, the largest withdrawals are for irrigated agriculture; for food production. There is limited scope to increase global area under irrigation – therefore we need higher yielding crops or improved irrigation to meet future food demands. Alternatively we need to seek to grow more food in those parts of the world with sufficient land and rainfall. In any case we need to produce food in a way that protects the natural resources it depends on – soil, nutrients and water – and on which we rely for other services – drinking water, climate regulation, flood protection, filtering of pollution.

One fifth of the world's population, 1.2 billion, live in areas of physical water scarcity (not enough water to meet all demands). About 1.6 billion live in basins affected by economic scarcity (lack of investment in water or lack of human capacity to satisfy the demand for water). Lack of adequate water and sanitation causes 5-10 million deaths annually; 80% of all sickness and disease is attributable to inadequate water and sanitation. The MDGs of hunger alleviation, poverty alleviation, sanitation, water supply and environmental sustainability are all linked to water-related issues.

Conflicts over water have taken place and seem set to increase. "The fighting in Darfur, Sudan resulted from water shortage and subsequent fighting between farmers and herders" (Ban Ki-moon 2008). Water may be key to solving Middle eastern conflict.

Recent work by a group of researchers led by Professor Vorosmarty from New York and published in September 2010 has shown that richer nations have been able to improve their water security through investment in more storage and supply infrastructure. Rich nations tolerate high levels of water stress and reduce their negative impacts through infrastructure development.

Lack of water infrastructure in Ethiopia plus its climate and hydrological vulnerability take a 38% toll on GDP. While Cambodia, Indonesia, the Philippines and Viet Nam lose an estimated $9 billion a year because of poor sanitation (2005 prices), or 2% of their combined GDP.

Climate change will affect the amount of rain and when it falls, the demand for water, water quality, and land use. Population growth means that the earth will have to sustain 2 billion more people in the next 20 years. The number of people affected by water scarcity may increase from 1.7 billion to 5 billion by 2025 irrespective of climate change; 60% of the world's people.

Here in UK we will see warmer and drier summers, wetter winters, more extreme rainfall events and a rise in sea levels. Our eastern counties will see summer evaporation exceed rainfall and that is going to change our landscape. If we experience an average temperature rise of 4 degrees, it is quite possible that our cities will experience 10 degrees rise and that will have significant water and energy implications. We will have up to 20 million extra people in England and Wales by 2050's, and over 3 million more homes mostly in the southeast, where water resource zones are already classified as water stressed.

In my personal view adaptation to the impacts of climate change in the UK will only be achieved through a national programme of water storage; from water harvesting, green roofs and infiltration devices, to major projects of Aquifer Storage and Recharge and impounding reservoirs in our wet regions. The cost will be tens of billions of pounds but put that alongside the major investments in energy £200 billion over the next ten years, or HS2 £35 billion or even Crossrail at £20 billion. It is a cost we must face.

If we look at the water cycle, we see that for every 100 rain drops, only 36 reach the ocean. The competing uses for green and blue water on its journey for "Cloud to Coast" need us to understand better these competing uses and the impacts of exporting virtual water in goods and food. We need more simple and yet more flexible simulation models to allow us to optimise the use of water for society.

Virtual water can be expressed as water footprint; by person, nation, industry or product. Applied to nations, the concept permits assessment of external and internal footprints,

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often linked closely to trade. UK national footprint is $102Gm^3$/year of which 38% is internal (water in the UK), and 62% external (water in other countries).The UK average footprint per person is $4.5m^3$ per day; thirty times the 150 litres supplied by our water company. The remainder is the virtual water embedded in the food we eat, the beverages we drink, the clothes we wear, the cars we drive and so on. The UK is the sixth largest net importer of water in the world.

Work on virtual water flows between the world's regions reveals some interesting insights. Some water scarce areas of the world are net exporters, such as Australia. Why? Because they wish to trade on the global market their products such as wine and fruit. This means that international trade has the potential to save water globally if a water intensive commodity is traded from an area where it is produced with high productivity to an area with lower productivity. However, there is a continuing lack of correlation between countries hydrologically best suited to grow food and those that actually do. This has led to a view that virtual water might have a sub-optimizing characteristic in that its availability slows down adoption of water policy reform.

But where does the water used in production come from? Though there has been an emphasis on blue water through irrigation, there is now more focus on the potential of improving water security through rain fed crop production. Green water already comprises the majority of virtual water but virtual water trade can do more to reduce irrigation water demand. Unlike blue water, green water cannot be reallocated to other uses. Green water also has relatively few environmental externalities whereas blue water use is linked to water depletion, salinisation, water logging and soil degradation. Green water trade is constrained by: international trade agreements and subsidies (in the USA and Europe, these are leading to increased blue water use); land availability; technology eg agricultural efficiencies.

By importing from USA, Egypt saves $930m^3$/ton of water, but its trade with the USA results in a net global water loss of $777m^3$/ton, because more water is used in USA to grow wheat. However, based on blue water only, this trading saves $251m^3$/ton.

Water scarcity is being recognised as an increasingly critical issue for sustainability of life on our planet. Six high profile reports and papers have been published in the last 18 months:

- Global Water Security, prepared for John Beddington by an alliance of RAEng, ICE and CIWEM.
- Water in a Changing World, the third report of UN Water.
- Charting our Water Future, by World Bank, McKinsey and the 2030 WRG.

- Water: Our Thirsty World, in National Geographic.
- Innovative Water Partnerships, by the World Economic Forum.
- For Want of a Drink, a special feature in the Economist.
- September issue of Nature with the work of Vorosmarty and others on the links between water security, loss of biodiversity and GDP.

Economic theory tells us that it is easier to encourage funding if true economic value of water is realised. Without it, we get price-cost differential and long-term sustainability becomes unlikely. However, to what extent is water a human right and if so whose responsibility is it to deliver it and who should meet the costs? True water pricing and trading is rare, but Australia and Chile have introduced it in their water scarce regions.

On average in the UK we pay around £3 for each cubic metre of water we buy from our water company; and that serves our drinking, washing, cooking, garden, car washing, and sewerage needs for a whole week! It is interesting to compare what we get for that £3, with other everyday things such as a sandwich, a coffee or a pint of beer.

I believe that until we value water appropriately, we will not be able to face some of the challenges that I am describing today. The value of water in our ecosystems is taken for granted, and includes:

- **Provisioning services** include controlling water quantity and quality for consumptive use.
- **Regulatory services** include buffering of flood flows and climate regulation
- **Cultural services** include recreation and tourism
- **Support services** include nutrient cycling and ecosystem resilience to, for example, climate change

The report Charting our Water Future uses so-called "cost curves" to prioritise water sector interventions to close the supply-demand gap. The curve for India turns around traditional thinking by showing that a suite of measures starting with those that improve the efficiency of water in agriculture would make more sense, leaving major supply measures until later. In China, the work shows that a focus on improving industrial efficiency may mean that closing the gap could be achieved at a cost benefit.

The Innovative Water Partnerships work of the WEF suggests that communities, industry and government can work successfully together to find win-win solutions. For example treated municipal wastewater can be a resource for industry and agriculture, as are the biosolids which the treatment process produces. Traditionally, the private sector was never present at water policy discussions. However, things are changing and water risks are faced by many businesses and those that are realising this first are taking steps to secure their water. SAB Miller improved water efficiency through re-designing of breweries and investment in equipment with efficient consumptions of water and energy.

. . . the demand for embedded water products in one country can have very serious impacts elsewhere . . .

Governments can provide a **facilitating** role, ensuring **engagement of all stakeholders and promoting a shared resource** which makes misuse less likely. Through **demonstrating** which measures have the greatest impact, this can spur investment from the private sector.

UK government aims to ensure UK food security through strong UK agriculture, and international trade links that support developing economies. However, high reliance on international trade for our food security means high reliance on water management in the nations which are supplying the food.

The concepts of blue and green water, virtual water and water footprint, and of water scarcity are not yet taught effectively within the education curriculum – anywhere. There is a pressing need to promote the idea of water as a shared and valued resource in our schools.

So, is global water security achievable? And if so, how would we know that we had achieved it? What would it look like? Here are five "tests" which I propose:

- Affordable drinking water for all, to promote public health
- Sustainable sources of water for industry and its supply chain, to promote economic health
- Integrated management of water in all its forms and for all its users
- And linked to this, policy and trade reforms which encourage sustainable water resources development and which discourage conflicts
- Mobilisation of the substantial volumes of public and private funds, via transparent and fair regulatory regimes which correctly value water

The consequences of failure are very grim. We will see:

- more people without safe drinking water and sanitation.
- food security endangered in nations which are water scarce.
- more pollution in developing nations.
- more conflict over water which crosses boundaries.

The potential for water scarcity or lack of water security to destabilise the world is high.

I will conclude by saying that we need to widen and deepen the debate around the fundamental role played by water in all human activity on our planet; social, cultural and economic. We know there are many innovative ways to close the supply demand gap, it isn't that difficult in theory, but this requires multiple stakeholder engagement and this is where government can do much to facilitate and catalyse innovative water partnerships which have long term benefits and which overcome corporate, political, and financial timescales

There is enough water, probably enough to sustain 10 billion people on Earth. We just need to use it wisely especially our precious green water. That means growing food where there is reliable green water.

Finally, water professionals like me need to take this message outside of their cosy group – the "water box". Today, I am doing just that!